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SUBJECT: Progress Technical Report
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Principal Investigator: Bernd Jaehne

Enclosed is the progress technical report and SF298 for the above referenced grant.

Sincerely,

Nancy Wilson

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Enclosure

Air-Water Gas Transfer in Coastal Waters

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LONG-TERM GOALS

The long-range objective of this project is threefold: a) the investigation of the mechanisms of air-water gas transfer by field measurements, b) the development of novel instrumentation for insitu measurements of the gas transfer rate and the parameters controlling it, and c) the solution of the long-standing problem of a physically-based parameterization of the air-sea gas transfer rate.

OBJECTIVES

In interdisciplinary field experiments the influence of wind forcing, short wind waves, and surfactants on the air-sea gas transfer is studied in coastal waters. The measurements include the air-sea gas transfer rate with a temporal resolution in order of minutes using heat as a proxy tracer, the air friction velocity, water currents and turbulence, air and water temperatures, visible and IR radiative fluxes, the visco-elastic properties of surface films, and wave number-frequency spectra of short wind waves. The measurements of the air-sea gas exchange rate with our instruments were combined with concentration measurements of carbon dioxide and dimethyl sulfide in the sea and the atmosphere, and direct flux measurements of carbon dioxide using the eddy correlation technique.

APPROACH

Using heat as a proxy tracer, the transfer rate is measured locally and with a temporal resolution of less then a minute. This technique offers an entirely new approach to measure air-sea gas fluxes of arbitrary gases and simultaneously to observe the micro turbulence at the ocean interface. Two independent techniques have been developed and successfully applied during field experiments. Both techniques use extended image sequences of the ocean surface temperature with and without artificial heating. The active technique estimates the time constant of heat transfer from the temporal decay of a heated spot at the ocean surface. Measuring the spatiotemporal temperature distribution on top of the aqueous mass boundary layer, heat patterns could be observed that directly revealed the horizontal structure of surface-near turbulence. Together with a physical modeling of the underlying transfer processes the passive technique allowed to compute transfer rates directly from the surface temperature distribution without artificial heating. The active heat spot-tracking and the passive statistical method deliver consistent results.

This project is conducted in cooperation with Dr. Erik Bock, Dr. Nelson Frew, and Dr. James Edson from WHOI and Dr. Tetsu Hara from the University of Rhode Island. The field experiments include two major components. One experiment took place in July 1997 with partial support from the NSF CoOP program. Additional longer-term measurements are planned in the year 1999 to fill in gaps in the range of conditions in the vicinity of the new SIO Marine Observatory, a platform about a mile off the Scripps Pier.

WORK COMPLETED

During the recent CoOP East Coast experiment from July 1 to July 18, 1997, the CFT instrument was used for the second time in the field. The cruise started from coastal waters at Martha's Vineyard sound south of Cape Cod, MA, leading to several Gulf Stream transects halfway to the Bermuda islands. Although no high wind speeds were encountered (maximum 8.4 m/s) the experimental conditions include a large variability in physicochemical surface conditions ranging from coastal waters with high surfactant concentrations up to very clean, deep blue waters close to the Bermuda islands. Measurements could be taken on 15 days in total. A first evaluation of the data showed that it will be possible to get good data from measurements at up to 10 days. Details are contained in the following table. The last column indicates the estimate of the quality of the data and additional comments.

CFT boom conditions, CoOP 97

JD	Time (UT)	Wind (m/s)	Conditions/patterns
188	01:25:34 - 02:52:00	0.0 - 0.9	Fair, high humidity, no waves
188	09:17:10 - 11:25:50	0.7 - 1.9	Fair, sky reflexes visible
189	01:32:07 - 02:15:39	4.0 - 4.3	Bad, foggy
190	02:47:26 - 05:33:30	1.0 - 3.1	Good, low fluorescence TOPEX crossing
191	00:08:42 - 03:02:40	6.3 - 8.3	Good, sky reflexes
192	10:12:14 - 13:16:45	1.5 - 2.7	Rain
193	09:21:42 - 13:49:13	2.0 - 4.7	Excellent, clear sky, frequent surface renewal visible
194	00:18:41 - 00:45:45	4.7	Excellent, clear sky
194	08:12:34 - 11:25:18	2.5 - 4.1	Good, foggy, small scale structures, surface renewal visible
194	18:43:31 - 19:53:12	4.5 - 5.3	Fair, daytime, sun reflexes, TOPEX crossing
195	08:50:50 - 11:16:03	4.9 - 5.8	Bad, foggy, sky reflexes
196	09:31:20 - 13:05:45	4.9 - 6.3	Bad, high humidity, sky, reflexes
197	00:53:43 - 03:08:55	4.7 - 5.8	Fair, high humidity
198	00:40:50 - 05:25:41	6.7 - 8.4	Fair, clear sky, reflexes
199	00:44:26 - 02:01:50	6.7 - 7.2	Bad, clear sky, reflexes

Wind wave spectra from the scanning laser slope gauge measured and evaluated from the WHOI/URI group are available for 6 of the 10 conditions for the same time periods.

RESULTS

The main data evaluation period will be from October 1998 through June 1999. During this period Dr.Erik Bock will be a visiting scientist at Heidelberg University and work together with Dr. Haussecker and the PI on the data.

Some preliminary results are already available:
1. The rates at low wind speeds are significantly higher as predicted by the empiric relationships based on laboratory data. This is not surprising. At low wind speeds there is still a residual turbulence in the ocean, which is not present in the laboratory facilities.
2. The data rather support surface renewal models of the than turbulent eddy models. Surface renewal is directly observable in the IR image sequences showing surface patches washed away statistically even at low wind speeds (Haussecker et al., 1998).
3. The surface velocity field derived from infrared image sequences clearly shows convergence and divergence zones that violate the two-dimensional continuity equation and thus also indicate the importance of surface renewal (Jaehne et al., 1998).

IMPACT/APPLICATIONS

We envision that the methods developed so far in this research project are only the beginning of a new interdisciplinary research area that merges chemistry, applied optics, fluid mechanics, and image processing techniques to gain an unprecedented insight into the mechanisms of small-scale air sea interaction processes (Jaehne, 1995; Jaehne and Haussecker, 1998).

RELATED PROJECTS

The activities in this project are closely related to the NSF CoOP project "Air-Sea Gas Exchange in Coastal Waters." Both projects focus on the air-sea gas exchange at the interface and thus support each other. In cooperation with the image processing group of the PI at the Interdisciplinary Center for Scientific Computing (University of Heidelberg, Germany), new algorithms are being developed for the local analysis of the surface flow image sequences from the IR image sequences within a research unit funded by the German Science Foundation (DFG) (Jaehne, 1997a and b; Jaehne et al, 1998; Haussecker and Jaehne, 1998).

PUBLICATIONS

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AWARDS

DAGM Award 1997 for the contribution ``A tensor approach for precise computation of dense displacement vector fields", by H. Haussecker and B. Jaehne.